A2 Concluded

The paragraph beginning at page 9, line 8, has been amended as follows:

FIGURES 14A-14E are simplified diagrams of the Electromagnetic Locating (EML) tool together with signal timing.

The paragraph beginning at page 11, line 29, has been amended as follows:

A3

The sequencer 29 is a specialized stepping relay that serves to connect the output 21 to a single pin on the connector 32 while grounding all the other pins. The relay is advanced by a stepping motor 30 under control of the microprocessor 13 by way of a stepping motor controller 31. One mechanical implementation of this sequencer is shown in FIGURES 4A-4B and will be discussed next. The harness adapter 34 serves to provide a connector 35 that mates to the harness to be tested. The number of pins on the harness can be up to the number of pins on the MED tool connector 33. In operation, the number of pins is inputted to the microprocessor and it controls the sequencer to switch between these pins only.

The paragraph beginning at page 12, line 6, has been amended as follows:

FIGURES 4A-4B show the top and side views of a mechanical sequencer. A stepper motor 30 rotates a metal disk 31 that has flexible wires 32 which contact vertical pins 33 set into a circuit board 37. The metal disk is electrically connected to the relay 28 (FIGURE 3) and each vertical pin connects to a pin on the connector 32 (FIGURE 3). One of the flexible wires 32 on the disk 31 is missing to allow a separate flexible wire 34 to contact the pin at that position. This wire is attached to a slip ring 35 that is electrically isolated from the disk 31 and connected via a contact 36 to the output 21 (FIGURE 3) of the MED tool. The stepper motor is made to turn in a counterclockwise direction only and the step size selected to align with the pins. In this manner, each time the motor is stepped, it advances one pin, applying the output 21 (FIGURE 3) to a

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single wire and grounded all the rest of the wires. Some feedback mechanism, not shown, must be included to allow the microprocessor to know where the starting point is.

A5 concluded

The paragraph beginning at page 14, line 14, has been amended as follows:

A6

Referring again to FIGURE 3, a second basic functional block of the MED tool is the high-speed circuit 22 that enables the device to measure the distance down the cable to the fault. The input to this circuit is a high-speed circuit taken from the WUT at point 21 via a 200:1 AC voltage divider formed by resistors 24 and 25. Careful layout and shielding must be employed to allow this divider to operate effectively at up to 1 GHz. The scope traces shown in FIGURE 10 and 11 were obtained by feeding the 50 ohm output from this divider directly into a 50 ohm, 1 Ghz bandwidth oscilloscope. The first trace, shown in FIGURE 10, shows the signal produced by a first micro-energy arc discharge 13.7 ft down a 56 ft cable harness. The harness is a twisted triplet of 10 gauge, Teflon-insulated aircraft wires. The vertical scale is 200 volts/div and the horizontal 50 ns/div. The width of the initial negative pulse is about 40 ns which is twice the transit time for 13.7 ft. FIGURES 12A-12G show the same harness with a second micro-energy arc discharge produced 48 ft down the cable harness. In this case, the initial pulse width is seen to be 136 ns, or twice the transit time for 48 ft. The purpose and function of the high-speed circuit 22 (FIGURE 3), therefore, is to measure the width of this initial pulse and, from that measurement, calculate the approximate position down the harness where the fault is located.

The paragraph beginning at page 16, line 1, has been amended as follows:

A5

The novel charts in FIGURES 12A-21G and 13A-13G explain more thoroughly the signal propagation, reflections and resulting waveform construction in the cases of FIGURE 10 and 11, respectively. Referring first to FIGURES 12A-12G, we see as the center trace i_{arc}. This is a plot of the current through the arc which is, in this case, located 13.7 ft down a 56 ft harness.

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A5 cont

The arc current initially rises at time = 0 as shown on either of the two time axes at the top and bottom of the chart. This current through the arc results from the effective transmission lines on each side of the arc discharging into the arc. Thus, $i_{arc(start)}$ is a plot of the current flowing from the portion of the cable harness extending from the start of the harness to the arc and $i_{arc(end)}$ is a plot of the current flowing from the portion of the cable harness extending from the arc to the end of the harness. The second trace from the top, labeled Distance, shows the progression of the traveling wave edge, starting at the arc at 13.7 ft and bouncing back and forth to the start of the cable at 0 ft. A mathematical analysis by the present inventor of the static conditions just before and after the arc initially fires shows that the arc firing produces two negative steps of amplitude –V, one traveling in each direction away from the arc. In the case shown in FIGURES 12A-12G, we have an initial applied voltage of +800 volts and, therefore, when the arc strikes we get a first -800 volt edge traveling towards the start of the cable, as indicated by the edge symbol with an arrow through it just to the right of the upper distance axis, and a second -800 volt edge traveling towards the end of the cable, as indicated by the edge symbol near the lower distance axis. Referring back to the upper distance plot, when this edge arrives at the start of the cable, which is a high relative impedance, we get a positive reflection with a reflection coefficient $\rho = +1$, and the 0 to -800 volt edge proceeds back towards the arc. The effect of this edge reflecting off the start of the cable is to cause the voltage to go from its original +800 volts to the –800 volts of the traveling edge. This produces the first 1600 volt negative edge one would observe at the start of the cable, as indicated by the upper trace labeled V_{start}. Note the time axis on the top shows that 19.3 ns has elapsed at this point. The 0 to –800 volt edge now proceeds back towards the arc as indicated on the upper distance plot. When it reaches the arc, because the arc is a relatively low impedance, the edges experience an inverting reflection, this time with a reflection coefficient $\rho = -0.75$. This 0 to +600 volt edge now travels back toward

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A5 Concluded

the start of the harness. When it arrives, it causes the waveform at V_{start} to rise back up, but not quite back to the starting voltage because of the reduced reflection coefficient at the arc. The pulse width, shown as Δt_{arc}, is thus equal to twice the transit time for the traveling wave to span 13.7 ft. It should be noted that, as shown on the lower half of the charts in FIGURES 12A-12G, a similar waveform is produced at the other end of the cable harness, the width of the first pulse being proportional to the distance from the arc to the end of the harness.

The paragraph beginning at page 17, line 6, has been amended as follows:

FIGURES 13A-13G show the same similar charts, but for the waveform depicted in FIGURE 11. In this case, the arc is located 48 ft down the same 56 foot long harness. The explanation follows from the above description.

The paragraph beginning at page 17, line 15, has been amended as follows:

A6

As noted, the received waveforms shown in FIGURES 11 and 12A-12G were taken on a twisted triplet of wires, one wire being the WUT, another connected to ground, and the third wire floating. If this third wire is instead connected to ground, the amplitude of the first pulse will be attenuated because grounding the wire causes an inversion on its reflection of the coupled signal. While the width can still be measured, it may be, in some cases, desirable to provide a sequencer that is capable of producing the best possible signal. To achieve this, the sequencer must be able to connect each wire either to power, to ground, or leave it floating. The sequence of operations in this case is as follows:

The paragraph beginning at page 18, line 21, has been amended as follows:

A7

Referring now to FIGURES 14A-14E, a simplified representation of a harness connected to an MED tool that is producing a micro-energy arc 42 is shown at the top of these figures. The two dimensional EML tool consists of 3 separate portable units—a controller unit and two separate Receiver units. The controller 43 is held in hand by the user, and the Receiver units 44

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A2 Concluded

and 45 are placed somewhere near or beyond the ends of the harness under test. The two Receiver units 44 and 45 each have an antenna to receive the electromagnetic radiation and are each connected to the controller unit 43 by a coaxial cable. When an arc strikes, the fast falling edge produced will be both conducted down the harness in both directions away from the arc and radiated into space in all directions. The energy traveling through space will propagate at the speed of light while the energy traveling along the harness will move at about 60-70% of this speed.

The paragraph beginning at page 19, line 1, has been amended as follows:

In FIGURES 14A-14E, the distance from the arc to the Receiver unit labeled A 44 is shown as *A* and the distance from the arc to the Receiver unit labeled B 45 is shown as *B*. The lengths of the coaxial cables are made equal and shown as *C*. When the arc strikes, the leading edge of the discharge will propagate into space at an initial time 0 shown at 46. At a time $b = B/\vartheta$ where ϑ is the speed of light, Receiver B will receive the impulse 47, use threshold detection to convert it to a digital pulse, and forward the digital pulse to the controller through the coaxial cable. The controller receives the digital pulse 49 at a time $c = C/\varphi$ later, where φ is the propagation speed in the coaxial cable. Receiver A sees the same radiated impulse 48 from the arc at a later time $a = A/\vartheta$, converts it to a digital pulse and forwards it on to the controller arriving as shown at 50. Though we cannot know the time 46 that the arc actually struck, we can measure the difference in time between the two received pulses, i.e., the time $a - b$. By making the two receivers identical circuits to produce equal processing delays, and the two coaxial cables the same length, these added delays are cancelled out in the difference.

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